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Original article

Quantitative analysis of traction in the glenohumeral joint. In vivo radiographic measurements

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SUMMARY. *Purpose:* To analyse change in distance between the humeral head and the glenoid fossa during traction in the maximally loose-packed position (MLPP) and the maximally closed-packed position (MCP) under standardized conditions.

Subjects: Six healthy subjects (three male and three female) with a mean age of 40.5 years, volunteered to participate in this study.

Materials and methods: Subjects were placed with the right shoulder in a modified shoulder brace (Otto Bock Armabduktions-Orthese in Modular Bauweise®) in 45° abduction in the plane of the scapula with neutral rotation (MLPP). A standard anterior–posterior radiograph of the glenohumeral joint was made. A 14 kg traction force was applied for 40 s, and a second radiograph was made. The same procedure was repeated with the shoulder placed in the MCP, which was 90° abduction and 90° external rotation. A radiologist, blinded for the variable traction or no traction, performed all radiographic measurements. Measurements were made on the same radiographs on two separate occasions (O1 and O2) with a 2-month interval.

Results: No significant differences were found in mean distance between the humeral head and the glenoid fossa during traction in the MLPP compared to traction in the MCP (O1: $P=1.00$ and (O2: $P=0.63$).

Conclusions: Application of a 14 kg force does not result in a significant increase of distance between the humeral head and the glenoid fossa. No significant difference was found between the change in distance of the humeral head and the glenoid fossa after traction in the MLPP compared to traction in the MCP.

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INTRODUCTION

Restricted shoulder range of motion (ROM) is a common condition encountered in daily orthopaedic physical therapy practice and remains challenging to treat. Clinicians frequently apply manual therapy

techniques including traction, glide mobilizations and manipulations to improve the ROM of the glenohumeral joint. According to manual therapy textbooks, traction can be used as a diagnostic tool to assess joint play, or as treatment to relieve pain or to improve joint mobility (Kaltenborn 1985; Mink et al. 1990; Frisch 1996). Different grades of traction have been defined, ranging from Grade 1 to 3 (Kaltenborn 1985). In Grade 1, there is no appreciable joint separation. Grade 1 represents the force necessary to abolish the compressive forces acting on the joint. In Grade 2, the slack is taken up from the tissue surrounding the joint, which are then tightened. Finally in Grade 3, additional force is applied and the soft tissues surrounding the joint are stretched and separation of the joint surfaces is achieved. Joint play is defined as an accessory motion, not under voluntary control, produced with a short, linear,

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passive bone movement. Joint play motions used in Manual Therapy are traction, compression and gliding. These motions are used mainly to assess how much 'play' or motion there is between two articular surfaces of a joint, and determine hypomobility or hypermobility of a joint system (Kaltenborn 1985). Traction, when used for joint play testing, is preferably performed in the maximal loose-packed position (MLPP) of the joint (for the shoulder: 55° abduction, 30° horizontal adduction and the forearm in the transverse plane). It is generally assumed that in the MLPP the joint play can be appreciated best because the joint capsule is most relaxed (Kaltenborn 1985). Dvorak and co-workers (Dvorak et al. 1997) stated that up to 5 mm of separation of the joint surfaces is physiological during joint play testing. In the maximal closed-packed position (MCP) (for the shoulder: 90° abduction and 90° external rotation), the joint capsule and ligaments are maximally taut and there is maximal contact between the joint surfaces. In the MCP the articular surfaces cannot be separated by traction forces according to Kaltenborn (1985). Thus, a greater amount of separation between the joint surfaces might be expected when applying traction in MLPP compared to traction in the MCP. However, these claims about joint separation have never been substantiated by means of research. In a pilot study by Gielen et al. (unpublished data) traction was applied to the glenohumeral joint in approximately 45° abduction in four subjects. Radiographs were taken during traction and no separation of the humerus from the glenoid fossa could be demonstrated.

The aim of this study was to analyse separation of the humeral head and the glenoid fossa during traction in the MLPP and the MCP under standardized conditions.

MATERIAL AND METHODS

Subjects

Six healthy volunteers, three men and three women, with a mean age of 40.6 years (range: 33–51) participated in this study. Five subjects were right-handed and one was ambidextrous. Three were involved in recreational sports (two in running and one in tennis). None of the subjects had a history of previous shoulder injury, surgery or had experienced any shoulder symptoms 6 months prior to and at the time of the study. All subjects had normal pain-free ROM being equal to the non-tested side. Prior to the study a standard radiograph was taken of the right shoulder and no abnormalities or degenerative changes were observed on radiographic films, thus all shoulders were classified as normal by the radiologist involved in the study.

We followed the principles outlined in the Declaration of Helsinki. The nature, purposes and risks of the research were explained to the volunteers by the researchers and informed consent was obtained. All volunteers were instructors in manual therapy who wanted to know whether traction did indeed separate the joint surfaces or not. They were aware that participating in the study meant repeated exposure to radiation. The subjects were free to withdraw from the study at any time.

Preliminary study

In a preliminary study, the maximal traction force that would normally be applied to the glenohumeral joint was determined. Twelve experienced manual therapists were instructed to apply a maximal amount of traction to the glenohumeral joint of a volunteer as they would do during glenohumeral mobilization. As a prerequisite, the traction had to be tolerated well by the volunteer. A spring gauge with a scale in kilograms (Federwage, Regensburg, Germany) was used to record the amount of force applied. The spring gauge was calibrated before and after each test. The spring gauge was attached to a cuff wrapped around the upper arm of the subject, as close to the glenohumeral joint as possible. The subject was seated on a stool with the glenohumeral joint shoulder in 45° abduction. A lateral, slightly anterior and superior directed pull was applied, as described in the textbooks (Mink et al. 1990; Frisch 1996). The subject had no difficulty relaxing during these test trials. The mean value of the traction applied by the 12 therapists was 12 kg (range: 5–14 kg). Therefore, 14 kg was used in the remaining part of the current research because it was believed that this force would be sufficient to produce increase in distance between the humeral head and the glenoid fossa.

Test procedure

Before traction was applied each subject performed 20 repetitions of active arm elevation of the right shoulder as a warm-up. The right shoulder of the subjects was placed in a modified shoulder brace (Otto Bock Armabduktions-Orthese in Modular Bauweise®, Göttingen, Germany). This brace held the shoulder in a position of 45° abduction in the plane of the scapula and in neutral rotation (MLPP). The abduction position was verified using a goniometer (Fred Sammons, Inc. Brookfield, IL). The arm was secured with Velcro® straps to prevent any other movement except traction. The subjects were then placed at a distance of 1.15 m to the radiographic beam. A radiograph was taken without applying a traction force for reference values. The spring gauge was then attached with a metal hook to the arm cuff and an assistant applied a 14 kg traction force in a

lateral, slightly anterior and superior direction. The scapula was stabilized by a second assistant by pulling on a belt (Soft Belt[®], OTP, Minneapolis, MN) that was wrapped diagonally over the shoulder covering the acromion and the lateral margin of the scapula (Fig. 1). Traction was sustained for 40 s before the second radiograph was taken. During the test procedure volunteers and assistants were protected by means of standard safety measures (lead gloves and lead apron). The radiation dose per radiograph was <0.01 mSv and was within the recommended safety limit standards set by the European Community (European Commission 2000). The same assistants performed scapular fixation and application of the traction during the test procedure for all subjects. The shoulder brace was then adjusted to a position with the glenohumeral joint in 90° abduction in the scapular plane and 90° external rotation representing the MCPP. The radiographic beam was slightly adjusted as the scapula had moved to a more lateral position in the MCPP. Similar to the previous position (MLPP) one assistant stabilized the scapula and the other applied the traction. Again two radiographs were made, one as a reference without traction and one after 40 s of traction. Thus, in total, four radiographs were taken from each subject, two from the MLPP and two from the MCPP. During the test procedure, the subjects were asked whether they experienced any discomfort and whether they were able to relax.

Quantitative analysis consisted of comparative measurements of each position. The geometric centre of the humeral head and the glenoid fossa were determined, similar to the technique used by Petersson and Redlund-Johnell (1983) and were taken as reference points for measurements. The displacement of the humeral head with the application of traction was determined from these radiographs to the nearest millimetre with a standard ruler, as used in radiology. A radiologist, blinded for the dependant variable

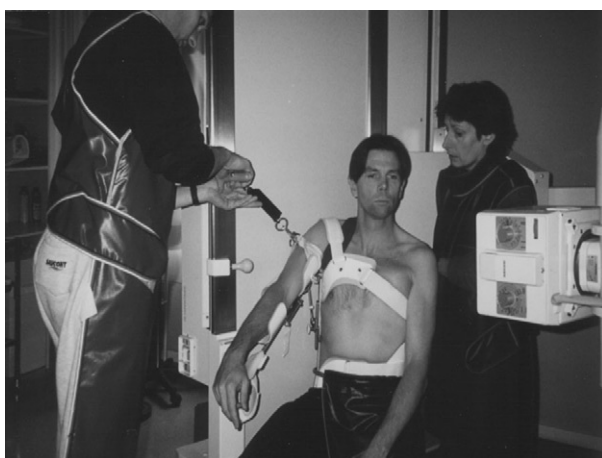


Fig. 1—Set up brace for experiment in MLPP.

traction or no traction, performed all radiographic measurements. To determine the intra-tester reliability of the radiologist, the measurements were made on the same radiographs on two separate occasions with a 2-month interval. The results from the previous measurements were withheld from the radiologist.

Statistical analysis

Data analysis was performed using SPSS for Windows version 10. Paired *t*-tests were used to analyse intra-observer reliability and to analyse the differences in the distance between humeral head and glenoid fossa before and after traction in the MLPP and the MCPP. Because of the small sample size, the results of the *t*-tests were verified using non-parametric tests (Wilcoxon signed rank sum test).

RESULTS

During the test procedure none of the subjects experienced discomfort and all were able to relax adequately.

Intra-tester reliability

The mean distance between the humeral head and the glenoid fossa assessed on occasion 1 (O1) differed significantly from that on occasion 2 (O2) (mean difference 0.4 mm) (Table 1). Of the 24 paired observations, 22 exhibited a difference between the first and the second observation of 1 mm or less. Because of this significant difference between O1 and O2, the results of both are given in the Tables 2 and 3. No significant change in distance between the humeral head and the glenoid fossa occurred with traction either in the MLPP or in the MCPP (Figs 2 and 3, Table 2). No significant difference was found between the change in distance of the humeral head and the glenoid fossa after traction in the MLPP compared to traction in the MCPP (Table 3). The results of the *t*-tests in Tables 2 and 3 were verified

Table 1. Intra-tester reliability of the radiologist. Mean and standard deviation of the distance between humerus and glenoid fossa (in mm) assessed on O1 and O2. Additionally, the mean difference between O1 and O2 and the 95% confidence interval of the difference is presented

O1 mean (SD)	O2 mean (SD)	Difference between O1 and O2 mean (SD)	95% CI
4.54 (0.86)	4.17 (0.55)	0.38 (0.58)	0.13 to 0.62

95% CI: 95% confidence interval; The difference between O1 and O2 is significant ($P=0.004$) (Results of *t*-test for dependent observations). It can be debated whether the mean difference (0.4 mm) is clinically relevant.

Table 2. Comparison of the distance between humeral head and the glenoid fossa (in mm) assessed before and during traction in the MLPP and MCPP on O1 and O2

	Before traction Mean (SD)	Traction Mean (SD)	Difference Mean (SD)	95% CI
MLPP (O1)	4.3 (1.0)	4.6 (1.1)	-0.3 (0.5)	-0.8 to 0.3
MLPP (O2)	4.0 (0.5)	4.2 (0.5)	-0.2 (0.3)	-0.4 to 0.1
MCPP (O1)	4.5 (0.5)	4.8 (0.9)	-0.3 (0.6)	-0.9 to 0.4
MCPP (O2)	4.3 (0.6)	4.3 (0.6)	0.0 (0.3)	-0.3 to 0.3

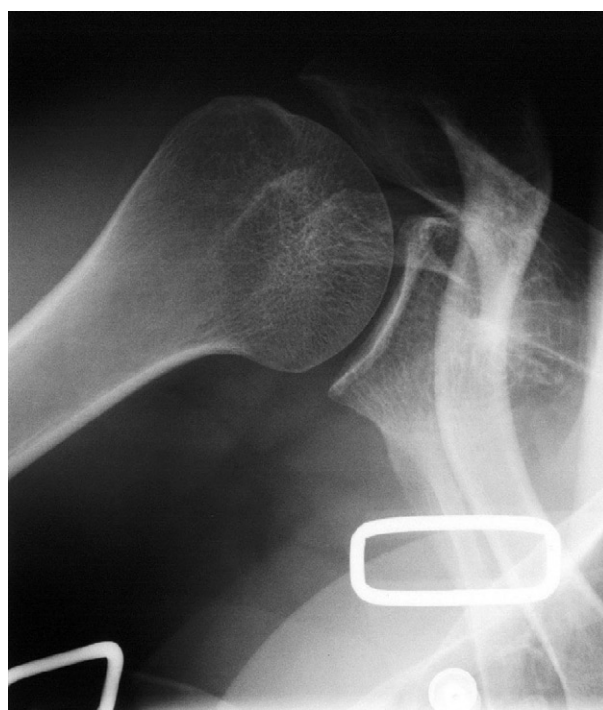
MLPP: maximally loose-packed position, MCPP: maximally close-packed position, O1: occasion 1, O2: occasion 2, 95% CI: 95% confidence interval (results of *t*-test for dependent observations).

Table 3. Comparison of the change in distance between humeral head and glenoid fossa (in mm) with and without traction assessed in the MLPP and MCPP on O1 and O2

Assessment	MLPP (<i>n</i> =6) Mean change (SD)	MCPP (<i>n</i> =6) Mean change (SD)	Mean difference in change (SD)	95% CI of the difference
Occasion 1	0.3 (0.5)	0.3 (0.6)	0.0 (0.8)	-0.9 to 0.9
Occasion 2	0.2 (0.3)	0.0 (0.3)	0.2 (0.4)	-0.3 to 0.6

MLPP: maximally loose-packed position, MCPP: maximally close-packed position.

The difference in change between MLPP and MCPP is non-significant (t_1 : $P=1.00$) and (t_2 : $P=0.63$) (results of *t*-test for dependent observations).

**Fig. 2**—Radiograph in MLPP before traction.**Fig. 3**—Radiograph in MLPP with traction.

using non-parametric tests because of the small sample size (Wilcoxon signed rank sum test). These non-parametric tests yielded non-significant results.

DISCUSSION

Based on the results of this study, a traction force of 14 kg does not induce an increase in distance between

the humeral head and the glenoid fossa in the MLPP, or in the MCPP.

The current paper is the first study to our knowledge that examined traction of the glenohumeral joint quantitatively under standardized conditions using radiographs to assess the distance between the humeral head and glenoid fossa. To ensure that all measurements were obtained under similar standardized conditions, the same test sequence was followed

for all subjects. Additionally, prior to the measurements all subjects performed 20 cycles of active arm elevation to precondition the soft tissue and reduce variations caused by the viscoelastic properties of the shoulder joint (Bigliani et al. 1992; Panjabi et al. 1994). The traction force was applied for 40 s before taking the radiograph. It was decided to use 40 s because when stretching muscle–tendon units for 30 s under laboratory conditions an increase in length occurs (Taylor et al. 1990). The traction force used was 14 kg because it was assumed that this force would be sufficient to produce a Grade 3 traction and an increase in distance between the humeral head and the glenoid fossa should occur. Additionally, 14 kg was the highest force used by manual therapists clinically, as measured in the preliminary study. Finally, 14 kg of traction was thought to be well within the zone of safety, Reeves (1968) demonstrated that forces of 26.8–61.7 kg are necessary to rupture the glenohumeral capsule or the glenoid labrum.

Abduction of 45° in the plane of the scapula was operationalized as the MLPP since it has been demonstrated that the capsulo-ligamentous structures are the loosest in this position (Warner et al. 1992). This position seems to be similar to the MLPP described by Kaltenborn (1985) and has the advantage that it can be reproduced more easily under research conditions.

Clinically, after a standard examination of the glenohumeral joint, manual therapists perform additional tests such as a joint distraction test. The magnitude and the end-feel of traction aids in the diagnostic process and in decision making about therapeutic interventions. In spite of the use of traction in daily practice, validity and reliability tests have not been carried out to the best of our knowledge. Our results indicate that it is unlikely that joint distraction occurs in a clinical situation in healthy glenohumeral joints. It has been stated that in the MLPP the greatest amount of joint separation is possible, relative to the MCPP, but the amount of separation has not been quantified (Kaltenborn 1985; Mink et al. 1990; Frisch 1996). Dvorak and co-workers (Dvorak et al. 1997) stated that up to 5 mm of separation is normal in the MLPP during joint play testing without providing evidence for the statement. The results of the current study do not support these statements because no increase in distance between the humeral head and the glenoid fossa occurred, in the MLPP or in the MCPP (Tables 2 and 3) when 14 kg of traction was applied. Joint play testing is performed with one hand of the therapist grasping the upper arm applying the traction while the other hand ‘fixates’ the scapula by holding the acromion and coracoid process (Kaltenborn 1985; Mink et al. 1990; Frisch 1996; Dvorak et al. 1997). The traction forces applied during joint play testing are probably less than the

14 kg applied in the current study. This may indicate that in a clinical setting the increase in distance between the humeral head and the glenoid fossa during traction are even less than that found in the current study.

It is our impression that it is mainly soft tissues that are moved during traction and that in spite of the therapist’s feeling of a ‘joint separation’, no such separation occurs.

Although this study was performed under standardized conditions it must be recognized that it was not possible to fixate the scapula entirely during testing, especially with the shoulder in 90° abduction, despite the maximal manual force applied by the assistant. However, the results of this study are probably not influenced by this inability to fixate the scapula because the distance between humeral head and glenoid fossa were measured on each separate radiograph. Further, the inability to fixate the scapula adequately during the experiment is probably similar to therapeutic conditions because the therapist fixates the scapula with a belt as well as performing the traction.

No significant differences were found in the mean distance between the humeral head and the glenoid fossa during traction in the MLPP compared to traction in the MCPP (O1: $P=1.00$) and (O2: $P=0.63$). This questions the use of the MLPP for joint play testing using traction based on the fact that a mean increase of 0.3 mm (O1) during traction was found. We are confident that such subtle motions cannot be detected manually through the soft tissues surrounding the glenohumeral joint. This paper cannot answer the question whether hypomobility or hypermobility can be assessed with traction as only healthy shoulders were included in this study.

Although it was not the aim of this study to describe the stabilizing factors acting on the shoulder joint, it appears that these stabilizing factors are sufficient to prevent separation with manual traction. Of particular interest may be the stabilizing effect of negative intra-articular pressure (NIP). Measurements of the NIP in 15 cadaver shoulders revealed that NIP changes depending on the position of the glenohumeral joint. Mean values ranged from –82.9 mmHg at 20° abduction to approximately –10 mmHg at 80° abduction (Inokuchi et al. 1997). Warner and co-workers demonstrated that NIP is not important for inferior stability at 45° abduction (Warner et al. 1992). It is uncertain at this time what the effect of NIP is on resistance against traction. It may be possible that NIP is able to resist larger than the traction forces used in this study, thereby preventing an increase in distance between the humeral head and glenoid fossa. However, the studies mentioned have analysed the effect of NIP on translations (Warner et al. 1992; Inokuchi et al.

1997). Therefore, the effects of NIP on traction are unknown.

Several limitations of the current study should be taken into consideration. The study sample was only six subjects and as a result the chance of a type 2 error is considerable. However, looking at the results in Tables 2 and 3, the mean differences are very small and these differences might become statistically significant in a larger study. The clinical relevance of these small differences remains questionable. Secondly, muscle guarding may have been a source of error in this study but none of the volunteers mentioned that the traction was uncomfortable or that they could not relax. Thirdly, the intra-tester reliability of the radiologist was analysed using the *t*-test for paired observations. The difference between O1 and O2 was significant (Table 1). However, the mean difference between the values on the first occasion and the second occasion was only 0.4 mm. The clinical relevance of this difference is doubtful. Further, of the 24 paired observations, 22 demonstrated a difference between the first and the second observation of only 1 mm or less.

CONCLUSION

Application of a 14 kg traction force to the humerus does not result in a significant increase in the distance between the humeral head and the glenoid fossa in a healthy shoulder joint.

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